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(71) Applicants *(for all designated States except US)*: AVIMO LIMITED [GB/GB]; Lisieux Way, Taunton, Somerset TA1 2JZ (GB). MICRO ENGINEERING INC. [US/US]; Suite 120, 1428 Semoran Boulevard, Apopka, FL 32703 (US).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: RUSSELL, Sean [GB/GB]; Lydon, Monkton, Heathfield, Taunton, Somerset TA2 8NE (GB). SAUNDERS, Adrian [GB/GB]; 123 Thames Drive, Taunton, Somerset TA1 2TE (GB). LAFOREST, Larry, Adrian [US/US]; 3516 Paulette Street, Apopka, FL 32712 (US).

(74) Agents: CALDWELL, Judith, Margaret et al.; David Keltie Associates, 12 New Fetter Lane, London EC4A 1AG (GB).

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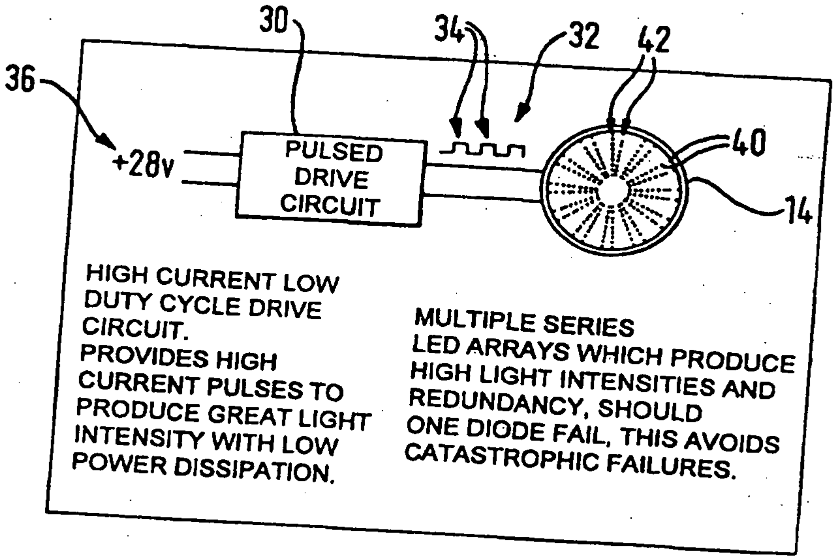
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PULSED DRIVE CIRCUIT
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HIGH CURRENT LOW DUTY CYCLE DRIVE CIRCUIT.
PROVIDES HIGH CURRENT PULSES TO PRODUCE GREAT LIGHT INTENSITY WITH LOW POWER DISSIPATION.
MULTIPLE SERIES LED ARRAYS WHICH PRODUCE HIGH LIGHT INTENSITIES AND REDUNDANCY, SHOULD ONE DIODE FAIL, THIS AVOIDS CATASTROPHIC FAILURES.

(57) Abstract

A warning light (10) for external use on an aircraft comprises a high–intensity light output light source (14, 20). The light source comprises a plurality of light emitting diodes (40) which are arranged to be pulsed with an overdriving signal (32) to produce a higher than normal intensity flashing light output. The overdriving signal (32) is generated by a pulsed drive circuit (30) in response to timing signals received from a flash pattern box at a rate of between 0.67 Hz to 1.67 Hz.

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WARNING LIGHT WITH LIGHT EMITTING DIODES

The present invention concerns improvements relating to lighting and more particularly, though not exclusively, to a high-intensity anti-collision warning light and a method of driving the same for external use on aircraft. The warning light can also be used for aircraft directional guidance systems or for marking hazards, such as television transmitter towers or artificial harbour walls, for land or sea vehicles.

In the field of anti-collision lights, there is a safety requirement to provide high-intensity pulsed light on the exterior of an aircraft to enable the aircraft to be visible in all weather conditions. The intensity of the light is therefore quite high typically being far greater than 100 Candela. Also, the flashing of the anti-collision light means that it is far more readily detectable than a light having a constant illumination. It should be noted that the flashing rate cannot be too high, namely above 25 Hz, because the light will be perceived by the human eye as being continuous.

Existing anti-collision lights, such as those described in US patents 3,903,501 and 5,293,304, for example, use xenon flash tubes to generate the required intensity of light. The xenon flash tubes are driven by a discharge of an electrical capacitance into the flash tube and so driving circuits include large banks of discharge capacitors. In addition, xenon flash tubes have high operating voltages that are generated in their driving circuits by transformers stepping up voltages to the required levels.

These requirements of often large electrolytic capacitor banks and bulky transformers mean that the driving circuits tend to be large, heavy and expensive. This is particularly disadvantageous when several lights and their respective driving circuits are provided in an aircraft where size and weight are very important issues. In addition, power consumption for these circuits can be undesirably high.

Conventional incandescent lamps that are used for aircraft navigation lights, for example, are far cheaper and require simpler lighter driving circuits. However, incandescent lamps cannot generate the high intensity of light output required for warning lights.

It is desired to overcome at least some of the problems described above and to provide an alternative to existing high-intensity warning light technology.

The present invention resides in the appreciation that light emitting diodes can be used to replace xenon flash tubes and can be appropriately controlled to generate the required high-intensity light output. Under normal operation, light emitting diodes cannot generate the required light intensity levels and previously this has mitigated against the use of light emitting diodes in high-intensity light output applications. However, the inventors of the present invention have determined that by overdriving a plurality of light emitting diodes with a pulsed control signal, the light output can be dramatically increased without overheating or otherwise damaging the light emitting diodes.

According to one aspect of the present invention, there is provided a warning light for external use on an aircraft, wherein a light source for the warning light comprises a plurality of light emitting diodes which are arranged to be pulsed with an overdriving signal to produce a higher than normal intensity light output.

The use of light emitting diodes obviates the need for large banks of capacitors and bulky transformers that are required for driving the xenon flash tubes. The driving circuit of the present invention can be realised in a simple control circuit that generates the required series of drive pulses at a relatively low voltage. Accordingly, the control circuit can be significantly smaller, lighter and cheaper than that of the prior art warning lights and also has far lower power consumption. This latter aspect can be particularly advantageous in remote locations where the warning light may be operating from a rechargeable battery power supply.

Another significant advantage of using light emitting diodes in place of xenon flash tubes is that the light emitting diodes need to be replaced far less frequently than flash tubes. For example, xenon flash tubes last a few hundred flying hours whereas light emitting diodes can last tens of thousands of flying hours. The longer operational life and greater reliability of light emitting diodes (light emitting diodes are less likely to malfunction than xenon flash tubes) can also provide significant cost savings in the long term. This is not only because of reduced costs of replacement components but more significantly because of the reduced costs of maintenance/labour. Furthermore, light emitting diodes are far more robust than flash tubes with far greater resistance to shock and vibration. For example, the light emitting diodes of the presently preferred embodiment of the invention, can withstand 5000 G of force and also random vibrations without breaking down.

Flash tubes also require shielding to prevent the electromagnetic radiation generated by the high-voltage transformers from affecting other equipment in the proximity of the warning light. A further advantage of light emitting diodes over flash tubes is that there is no requirement for this electromagnetic shielding because light emitting diodes do not require high-voltage transformers.

The light emitting diodes are preferably set out in an array. This advantageously allows the light emitting diodes to be provided in a compact unit with a high light output density. In addition, the array may comprise a plurality of groups of light emitting diodes, the groups being connected together in parallel and each group comprising a plurality of light emitting diodes connected in series. This arrangement incorporates built in redundancy which advantageously prevents catastrophic failure of the light emitting diode array because if one diode fails, the whole unit will not also fail. Rather, the series or string of diodes which contains the defective light emitting diode will fail and the other strings of diodes will be unaffected.

Preferably, the light emitting diodes are arranged to output a selected colour of light which is dependent on the selected mode of operation. This may be achieved by the light emitting diodes comprising selectable sets of light emitting diodes, each set being capable of emitting a particular colour of light. In this way, a single array of light emitting diodes, for example, can generate different warning signals depending on the colour of the light output.

A further advantage of using light emitting diodes in place of xenon flash tubes is that light emitting diodes generate specific narrow wavelength bands of light and for military aircraft applications the amount of infra-red light that is generated can be accurately controlled. Accordingly, the use of light emitting diodes is inherently night vision goggle (NVG) friendly because it does not blind pilots flying on NVGs with excess infra-red light, and also there is no need to use special filter glass for reducing excess infra-red light from the warning light.

The warning light may comprise a plurality of light sources. This is advantageous when the warning light is to provide an increased field of view in which case each source faces a different direction. For a maximal field of view, the plurality of light sources can be arranged about an axis to be radially outwardly facing and to illuminate substantially 360 degrees of view around the axis.

Preferably, the or at least one of the light sources comprises a plurality of infra-red light emitting diodes. The infra-red diodes provide a warning light which is detectable at night with NVGs. This is particularly for use on military aircraft during covert operations. The infra-red diodes are driven by a pulsed control signal in the same manner as the other light emitting diodes to generate the required high-intensity light output. When both infra-red and visible light sources are provided, the warning light can be switched between visible and covert operation modes. When viewed through NVGs the output of the infra-red light source appears identical to the visible light source. This aids night vision training because this type of training can advantageously be carried out in daylight conditions using NVGs.

The warning light may further comprise means for generating a sequence of drive pulses, each drive pulse having a magnitude sufficient to cause said relatively high-intensity light output. Such generating means can be provided on the light housing to provide a self-contained compact lighting unit. Also, the generating means is preferably configured to be operable in response to a received timing signal. The timing signal can be provided by an appropriate flash pattern box which can be positioned, for example, remotely from the warning light. The flash pattern box typically includes a microprocessor and associated memory which produce timing control signals at an appropriate rate which are used by the generating means to cause the light source to output light pulses which are perceived as regular intermittent illumination or as a regular sequence of light flashes. To assist in aircraft identification, for example, more complex flash patterns, such as a sequence of three short flashes followed by one longer flash, may be generated.

Preferably, the light output from the warning light is flashed at a rate between 40 to 100 flashes per minute, namely 0.67 Hz to 1.67 Hz. This rate ensures that the output of the warning light is relatively easy to detect visually by observers. Furthermore, this rate meets the requirements for International aviation authorities when the warning light is used as an anti-collision light on an aircraft.

The drive signals from the generating means to the light source are preferably in the form of a rectangular shaped waveform. This waveform provides an optimal light output over time from the light source as compared to other possible waveforms. The rectangular-shaped pulses preferably have a duty cycle of not more than 10%. This limit minimises the power consumption for the warning light whilst still providing sufficient on time for generating the required intensity of light output.

In a presently preferred embodiment of the present invention, the output of the light emitting diodes is controlled by the drive pulses varying the driving current supplied to each of the light emitting diodes. However, it is also possible to control the light output by the drive pulses varying the driving voltage applied to each of the light emitting diodes.

According to another aspect of the present invention there is provided a method of driving a warning light for external use on an aircraft, the method comprising pulsing a plurality of light emitting diodes which comprise a light source of the warning light, with an overdriving signal to produce a higher than normal intensity flashing light output.

The invention can alternatively be considered to be according to another aspect a method of driving a warning light for external use on an aircraft, the method comprising overdriving a plurality of light emitting diodes which comprise a light source of the warning light, with a pulsed driving signal that is greater in magnitude than the magnitude of the maximum normal operational driving signal for the light emitting diodes.

The present invention also extends to an anti-collision light comprising a warning light as described above. In addition, according to another aspect of the present invention there is provided a warning light as described above, in combination with a control means which is arranged to control a time sequence of light flashes output from the warning light.

Preferred embodiments of the present invention will now be described by way of example with reference to the accompanying drawings. In the drawings:

Figure 1 is a side view of an anti-collision light embodying the present invention;

Figure 2 is a cross-sectional view of the anti-collision light of Figure 1 taken through section AA′ as set out in Figure 3;

Figure 3 is an underside view of the base of the anti-collision light of Figure 1; and

Figure 4 is a schematic block diagram of the electrical circuit employed in the anti-collision light of Figure 1.

Referring now to Figures 1, 2 and 3, a presently preferred embodiment of the invention is shown in the form of an anti-collision light 10. The anti-collision light 10 is for use on the fuselage of a military aircraft (not shown) and provides 360 degrees of illumination around a central axis 12 of the light 10.

The anti-collision light 10 comprises six normally visible light emitting diode arrays 14 which are assembled in the lower portion 16 of an aluminium central housing 18. Eight infra-red light emitting diode arrays 20 are affixed to an upper part 22 of the housing 18. Each light emitting diode array 14,20 faces radially outwardly from the central axis 12 so as to cover the entire illumination range of 360 degrees.

The central housing 18 is mounted on a base plate 24 and is enclosed by a transparent plastics cover 26. However, the cover 26 may alternatively be translucent or made from glass. The cover 26 allows both the generated infra-red light and the visible light to pass therethrough. The cover 26 can be sealed to the edges 28 of the base plate 24 to provide a weather proof enclosure for the light emitting diode arrays 14,20.

A drive unit 30, for supplying the light emitting diode arrays 14,20 with appropriate driving signals, is mounted to the underside of the base plate 24. The drive unit 30 receives timing signals from a flash pattern box (not shown) and these signals are converted into drive signals 32 for each light emitting diode array 14,20. The drive signals 32 are distributed to the light emitting diode arrays 14,20 by wiring (not shown) between the drive unit 30 and each of the fourteen light emitting diode arrays 14,20.

Referring now to Figure 4, the details of the drive unit operation now are described. For the sake of convenience, Figure 4 shows the drive unit 30 controlling a single light emitting diode array 14. However, it is to be appreciated that the drive unit 30 controls each one of the light emitting diode arrays 14,20. The pulsed drive unit 30 receives its timing signals from a remotely positioned flash pattern box which is also not shown. The flash pattern box is typically connected to several anti-collision lights 10 and stores information for each anti-collision light 10 regarding the desired colour output, the desired flash rate and any changes to the flash rate.

The pulsed drive unit 30 takes the timing signals from the flash pattern box and converts these to the drive pulses 34 for the light emitting diode array 14. Each pulse 34 is rectangular in shape and the mark/space ratio is at least 1/10. In other words, the duty cycle for the drive signals 32 is 10% or less. The pulses 34 are current pulses which have a magnitude in excess of the diode array's stated maximum current rating. In this embodiment, the maximum current rating for a string of light emitting diodes is 50mA and each of the drive signal pulses 34 has a magnitude of 200mA. This generates an output which is well in excess of 100 Candela and can reach up to 1000 Candela. Accordingly, the light emitting diode array 14 is overdriven by the drive signals 32 but because the signal 32 is pulsed at a rate between 0.67 Hz and 1.67 Hz, the light emitting diode 14 does not overheat and there is no other long term damage.

The actual light output is dependent on the power input into the light source 14. Accordingly, the light output can be varied by changing the duty cycle of the drive signal 32 as well as its magnitude.

The drive unit 30 is powered by a +28 Volt power supply 36. The drive signals 32 are, in this embodiment, output at a constant voltage of +28 Volts which is the stated maximum operational voltage of the light emitting diode arrays. However, in another embodiment of the present invention, the voltage can be varied to overdrive the light emitting diode arrays to achieve the high-intensity light output. For example, the pulses 34 can be output at +30 Volts rather than +28 Volts.

The light emitting diode array 14 comprises a plurality of high-intensity output light emitting diodes 40. The light emitting diode array 14 has a plurality (24 shown in Figure 4) of groups or strings 42 of light emitting diodes 40. The strings 42 are connected together in parallel and each string 42 comprises a plurality (9 shown in Figure 4) of light emitting diodes 40 connected in series. If one diode fails, then the string 42 to which the diode 40 belongs stops working. However, as the other strings 42 are connected in parallel, the light emitting diodes 40 in these strings 42 continue to function correctly. This arrangement uses the built-in redundancy to prevent catastrophic failure of the light emitting diode array 14 if one diode 40 fails.

The light emitting diode array 14 is arranged to output a selected colour of light when the appropriate signals are received from the drive unit 30. The array 14 comprises sets of selectable strings 42 of light emitting diodes 40, the strings 42 of each set are capable of emitting a particular colour of light. In this particular embodiment, strings 42 of light emitting diodes 40 emitting visible red light and strings 42 of light emitting diodes 40 emitting near white light are provided alternately about the light emitting diode array 14. The strings 42 of the red light diodes 40 are connected together in parallel but are not connect to the white light diodes 40. Each type of string 42 is driven independently by the drive unit 30 in dependence on the selected mode of operation. Switching between the banks of diodes is carried out under control of the flash pattern box. However, this can also be carried out by regulating a control voltage within a switch box (not shown) in the cockpit.

The diode array 14 is a single unit with each diode and its interconnections forming an integrated circuit at the surface of a substrate. The substrate is made from a ceramic material which is supported on an aluminium base. For generating white light, the diodes comprise sapphire crystal coated with a phosphor.

The present invention is also applicable to other forms of warning lights such as lights for marking hazards on land and at sea, for emergency personnel and property identification and warning systems and for directional guidance systems. It may be that some of these applications require a lower minimum light-intensity level but the principle of overdriving the light emitting diodes to improve their light intensity output is still applicable.

Having described particular preferred embodiments of the present invention, it is to be appreciated that the embodiments in question are exemplary only and that variations and modifications such as will occur to those possessed of the appropriate knowledge and skills may be made without departure from the spirit and scope of the invention as set forth in the appended claims. For example, it is not necessary to have light emitting diode arrays covering 360 degrees of viewing angle. Rather, for forward anti-collision lights which require a narrower field of view, the light emitting diode arrays need only cover a smaller angle. Also, it is not necessary to provide the infra-red light emitting diode arrays 20, for commercial/civil aircraft for example. The light emitting diodes 40 can all be of the same type producing a light output of a single colour for a dedicated warning light, for example a visible white anti-collision light or a visible red anti-collision light. It is also not necessary for the diode arrays 14,20 to be circular, they can be any desired shape for example square shaped.

CLAIMS

1. A warning light for external use on an aircraft, wherein a light source for the warning light comprises a plurality of light emitting diodes which are arranged to be pulsed with an overdriving signal to produce a higher than normal intensity flashing light output.

2. A warning light according to claim 1, wherein the plurality of light emitting diodes are set out in an array.

3. A warning light according to claim 2, wherein the array comprises a plurality of groups of light emitting diodes, the groups being connected together in parallel and each group comprising a plurality of light emitting diodes connected in series.

4. A warning light according to any preceding claim, wherein the light source comprises a substrate on which is provided the plurality of light emitting diodes.

5. A warning light according to any preceding claim, wherein the light source is housed on a base mounting plate and is protected by a translucent or transparent cover.

6. A warning light according to claim 5, wherein the translucent cover comprises a light filter.

7. A warning light according to any preceding claim, wherein the light emitting diodes are arranged to output a selected colour of light in dependence on the selected mode of operation.

8. A warning light according to claim 7, wherein the light emitting diodes comprise selectable sets of light emitting diodes, each set being capable of emitting a particular colour of light.

9. A warning light according to any preceding claim, comprising a plurality of light sources wherein each light source comprises a plurality of light emitting diodes.

10. A warning light according to claim 9, wherein the plurality of light sources are arranged about an axis to be radially outwardly facing and illuminate substantially 360 degrees of view around the axis.

11. A warning light according to any preceding claim, wherein the or at least one of the light sources comprises a plurality of infra-red light emitting diodes.

12. A warning light according to any preceding claim, wherein the intensity of the light output is at least 100 Candela.

13. A warning light according to any preceding claim, further comprising means for generating the overdriving signal, the signal comprising a sequence of drive pulses, each driving pulse having a magnitude sufficient to cause said relatively high-intensity flashing light output.

14. A warning light according to claim 13, wherein the generating means is operable in response to a received timing signal.

15. A warning light according to claim 13 or 14, wherein each drive pulse is rectangular shaped.

16. A warning light according to claim 15, wherein the duty cycle of the sequence of pulses is lower than 10%.

17. A warning light according to any of claims 13 to 16, wherein the drive pulses vary the driving current supplied to each of the light emitting diodes.

18. A warning light according to any of claims 13 to 17, wherein the drive pulses vary the driving voltage applied to each of the light emitting diodes.

19. A warning light according to any preceding claim, wherein the plurality of light emitting diodes are arranged to be pulsed at a rate of 40 to 100 pulses per minute to produce a corresponding rate of flashing light output.

20. An anti-collision light comprising a warning light according to any preceding claim.

21. A warning or anti-collision light according to any preceding claim, in combination with a control means which is arranged to control a time sequence of light flashes output from the warning light.

22. A method of driving a flashing warning light for external use on an aircraft, the method comprising overdriving a plurality of light emitting diodes which comprise a light source of the warning light, with a pulsed driving signal that is greater in magnitude than the magnitude of the maximum normal operational driving signal for the light emitting diodes.

23. A method of driving a warning light for external use on an aircraft, the method comprising pulsing a plurality of light emitting diodes which comprise a light source of the warning light, with an overdriving signal to produce a higher than normal intensity flashing light output.

24. A warning light, an anti-collision light, a combination or a method substantially as described herein with reference to the accompanying drawings.

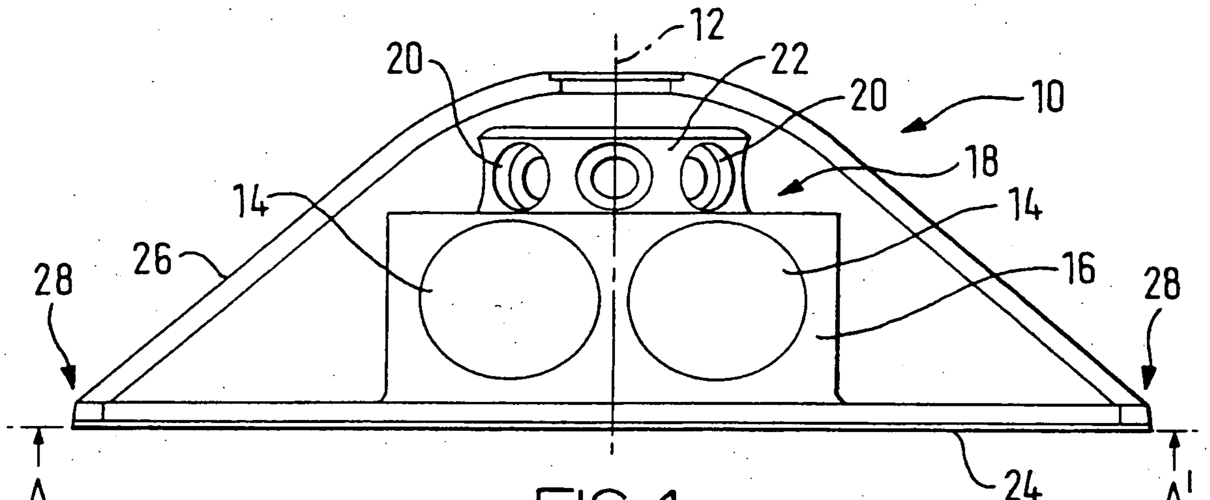
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FIG. 1

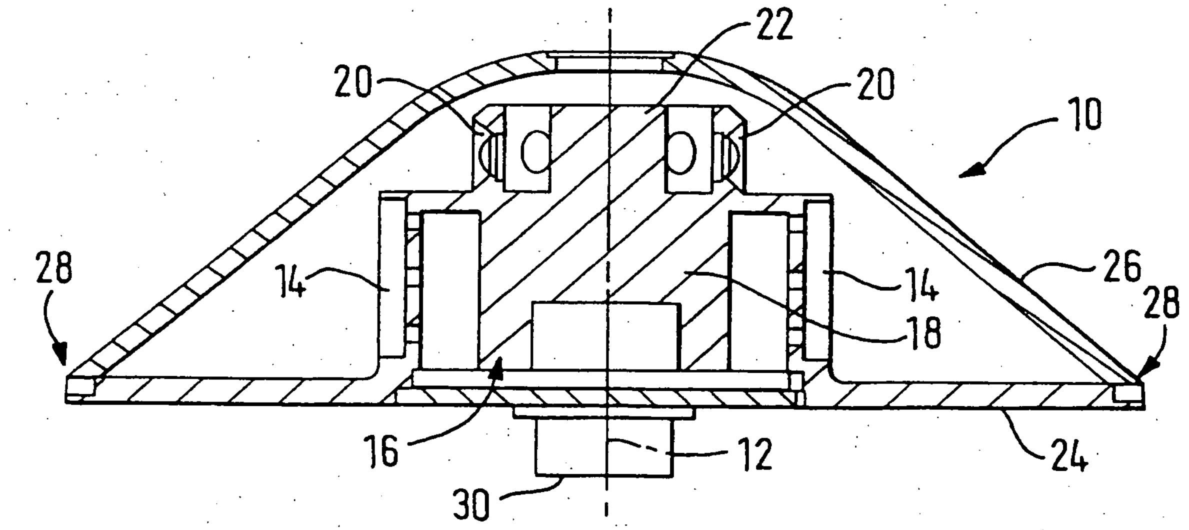


FIG. 2

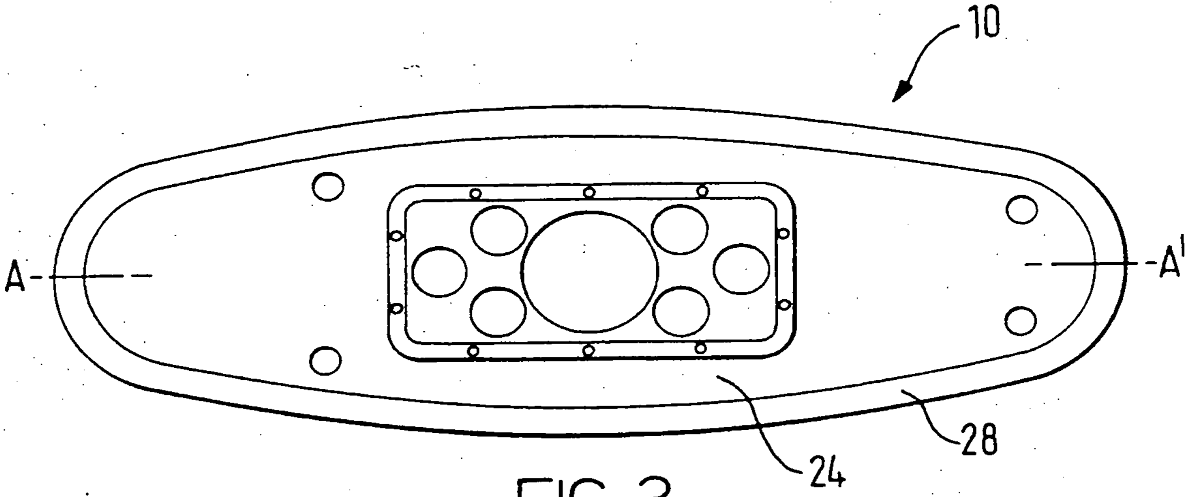
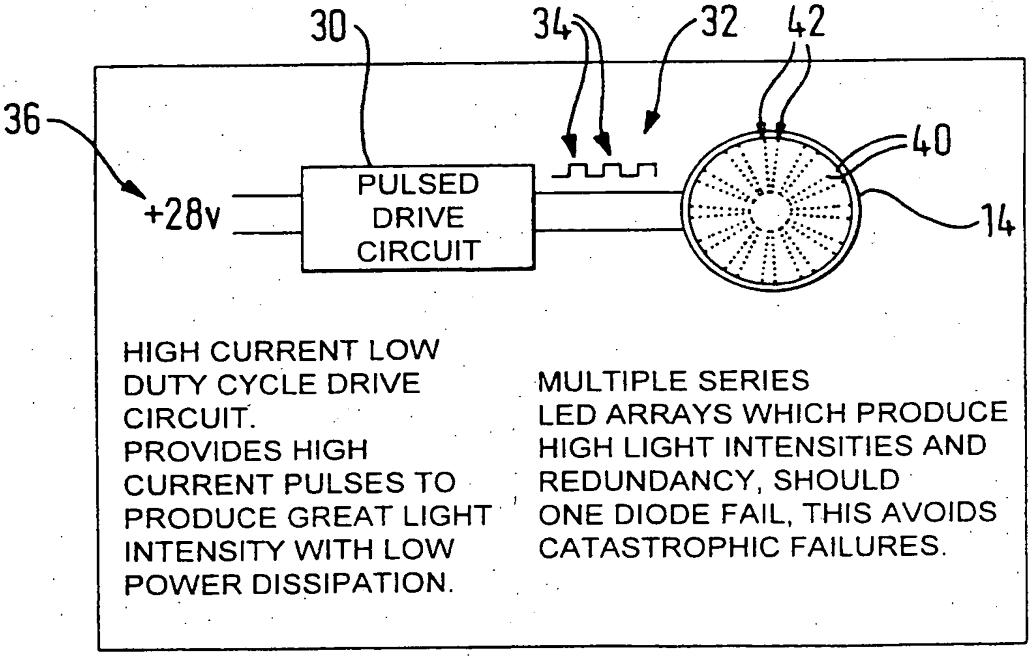


FIG. 3



HIGH CURRENT LOW DUTY CYCLE DRIVE CIRCUIT.
PROVIDES HIGH CURRENT PULSES TO PRODUCE GREAT LIGHT INTENSITY WITH LOW POWER DISSIPATION.

MULTIPLE SERIES LED ARRAYS WHICH PRODUCE HIGH LIGHT INTENSITIES AND REDUNDANCY, SHOULD ONE DIODE FAIL, THIS AVOIDS CATASTROPHIC FAILURES.

FIG. 4

INTERNATIONAL SEARCH REPORT

International Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B64D47/06 F21Q3/00 F21K7/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B64D F21Q F21K H05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	FR 2 711 884 A (SOLARTEC SARL) 5 May 1995 (1995-05-05) page 1, line 5 -page 2, line 23 page 3, line 24 -page 5, line 17 claims; figures	1-4,9, 13,14, 16,17, 19,21-24
Y		5-8, 10-12, 15,17, 18,20

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☒ Further documents are listed in the continuation of box C.

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European Patent Office, P.B. 5818 Patentlaan 2
NL – 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
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INTERNATIONAL SEARCH REPORT

In' tional Application No
PCT/GB 99/01596

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	GB 1 574 387 A (BOURBOULON H) 3 September 1980 (1980-09-03) page 1, line 21-34 page 1, line 47 -page 3, line 2 claims; figures	1-5,9, 13-16, 18,19, 21-24
Y		5-8, 10-12, 15,17, 18,20

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A		1-4,7-9, 11, 13-19, 21-24

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